CHAPTER 8.

Applications of the Biocriteria Process

Biocriteria, a critical tool for state agencies to use in protecting the quality of water resources, serve several important purposes: they help (1) characterize and classify aquatic resources, (2) refine aquatic life use categories, and (3) judge use impairment (i.e., they help determine attainment and nonattainment of designated uses). Additionally, biocriteria are used for (4) identifying possible sources of impairment (e.g., habitat degradation, flow regime changes, chemical contamination, energy alterations, or biological imbalance); (5) problem screening; (6) ranking and establishing priorities for needed remedial actions; and (7) assessing the results of new management practices. Other applications of the process include evaluating the adequacy of NPDES permits, and trend reporting for 305(b) reports.

Purpose:
To illustrate the importance of biocriteria in various areas of water resource management.

Stream Characterization and Classification

The process of biocriteria development requires that streams be classified according to type to determine which reference conditions and criteria are required. This classification must be done in each of the nation's ecoregions — as defined by climate, geographic, and geologic characteristics. Then, within these regions, the streams should be further categorized and their classes either combined or subdivided depending on whether they have similar or distinctive biotic compositions.

Initial classifications can be confirmed, refined, or revised on the basis of subsequent biological data. This continued monitoring makes the reference sites and derived biological criteria more certain, and helps the resource managers and biologists identify unique or particularly sensitive streams for special attention or protection. The following case study from North Carolina illustrates this point.

CASE STUDY — North Carolina

STATE	LOCATION	DATES
North Carolina	South Fork of New River	March–August 1990

The South Fork of New River forms the headwaters of the New River in North Carolina. The entire South Fork New River catchment is mountainous with generally steep, forested slopes. The floodplain is broad with

The classification and definition of designated uses of streams and rivers are important in developing and using biocriteria. Similarly, as biocriteria become established, the expanded database helps refine these classifications.

rolling hills; and land uses in the area are primarily rural and agricultural, including crop and dairy pasture production. Nonpoint source runoff from these uses has a high potential for water quality problems (NC Dep. Environ. Manage. 1978).

The North Carolina Environmental Management Commission classifies certain waters of the state as "outstanding resource waters" (ORW) if such waters have an exceptional recreational significance and exceptional water quality. Determining whether a North Carolina stream qualifies for reclassification as an ORW depends primarily on data collected by the Biological Assessment Group, which is part of North Carolina's biocriteria program.

To evaluate an ORW request for the New River, the Biological Assessment Group collected benthic macroinvertebrate samples from 21 riverine and tributary locations within the New River catchment. Main-stem river locations (the South and North Forks of the New River) were sampled using the Group's standardized qualitative collection method, which uses a wide variety of collection techniques (and 10 samples) to inventory the aquatic fauna. The primary output is a taxa list with some indication of relative abundance for each taxon (i.e., abundant, common, or rare). The combined number of species in the pollution-intolerant insect orders of Ephemeroptera, Plecoptera, and Trichoptera (EPT Index) is used with department criteria to assign water quality ratings. Unimpaired or minimally impaired streams and rivers have many species, while polluted areas have fewer species.

Based on analyses of the biological data (Fig. 8-1), excellent water quality was found at the ambient monitoring location on the South Fork New River near Scottsville and Old Field Creek, a tributary of the South Fork New River. Prior data have also consistently shown excellent water

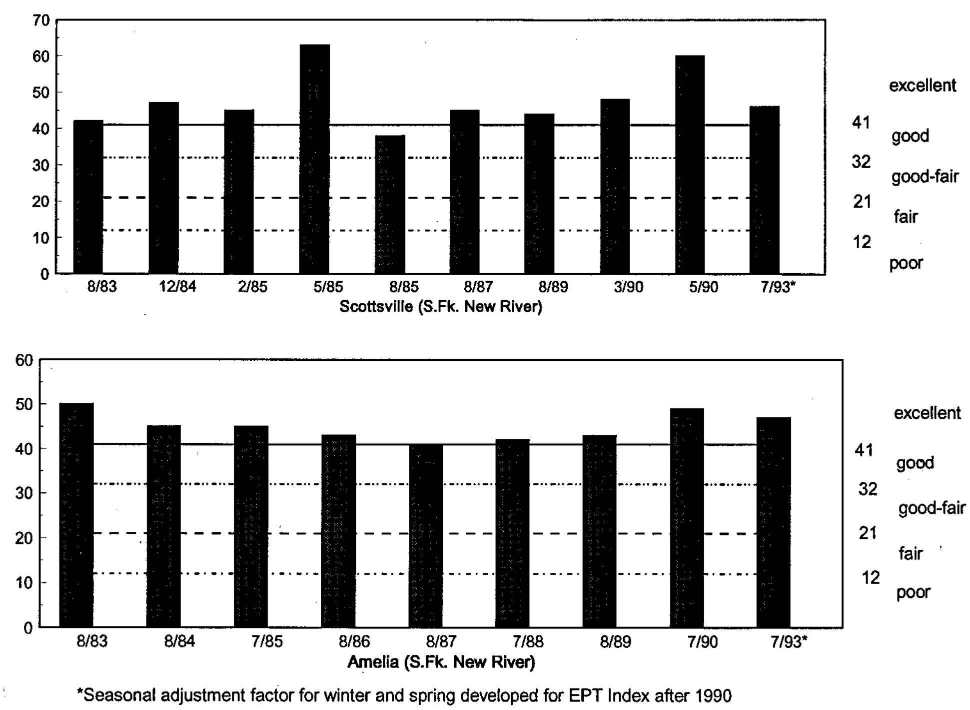


Figure 8-1.—EPT Index (number of taxa of Ephemeroptera, Plecoptera, and Trichoptera) for two locations on the South Fork of the New River, North Carolina.

quality at the South Fork New River near Jefferson and for the New River itself, below the confluence of the North and South Forks. A site on the North Fork New River also had excellent water quality, but repeated sampling at this site revealed that its samples fluctuate between good and excellent quality on a temporal basis. Until it achieves a more consistent water quality rating, this site on the North Fork will not be recommended for an ORW classification.

Old Field Creek has an outstanding brook trout resource. The South Fork of the New River has been designated as a Natural and Scenic River from the confluence of Dog Creek in the documented excellent reach of the river to its confluence with the New River. The New River — according to information provided by local canoeing outfitters — supports an unusually high level of water-based recreation.

It was, therefore, recommended that the South Fork New River from the confluence of Dog Creek to the New River, and the New River itself, to the last point at which it crosses the North Carolina-Virginia state line be designated ORW. The west prong of Old Field Creek (Call Creek) from its source to Old Field Creek, and Old Field Creek below its confluence with the west prong to the South Fork New River was also designated ORW. On the basis of biological data, the recommendation was accepted. The Commission reclassified these streams in December 1992, thereby ensuring that stricter point and nonpoint source regulations would be enforced in this region.

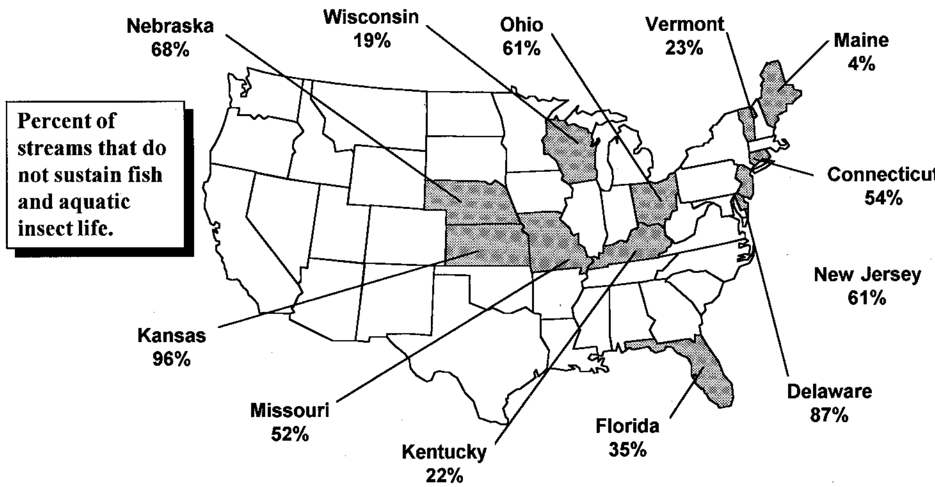
Refining Aquatic Life Uses

As a biocriteria program grows, the accumulated information helps state or tribal biologists refine the aquatic life use categories initially developed. That is, the additional information about the distribution and status of biota helps resource managers refine their categories of aquatic life use. The development of the "outstanding resource waters" category in North Carolina is an illustration of this process in which a less natural and diverse community characterizes the aquatic life use. Information obtained through biological surveys is used to explicitly characterize each aquatic life use. Other examples follow.

Oregon is presently developing state surface water categories based on aquatic life classifications. The proposed language for biological criteria in Oregon separates water resources into two categories. The first classification ("Outstanding Resource Waters") is for waters that shall be managed so that "resident biological communities . . . remain as they naturally occur and all indigenous aquatic species are protected and preserved."

The second category is for all other waters of Oregon. Waters in this class meet their use requirement if and when the following statement is applicable: "other waters of the state, including waters outside designated mixing zones, shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities" (Oregon Dep. Environ. Qual. 1991).

Maine has established four classes of water quality for streams and rivers (Table 7-2). The "high quality waters" of Maine are separated into two categories: one category contains waters meeting the highest goal of



Source: State 305(b) Reports, 1992-1994

Figure 8-2.—Examples from some states using biological assessments to determine aquatic life use support in rivers and streams. Failure to sustain fish and aquatic life is defined with respect to the reference condition in that state.

the Water Quality Act (no discharge, Class AA); the other contains waters of high integrity but minimally impaired by human activity (Class A). "Good quality water" is assigned to the second category: Class B. Waters in Class B meet their aquatic life use requirement if and when all indigenous aquatic species are supported and only nondetrimental changes in community composition occur. The fourth category Class C, is reserved for the lowest quality waters. Waters in this class also meet their use requirement if and when all indigenous aquatic species are supported. However, changes in species composition may occur in Class C waters, even though the structure and function of the aquatic community must be maintained (Davies et al. 1991).

These classifications and their refinement depend on a well-established biocriteria program supported by regular, representative biosurveys. In fact, the procedure has been so successful that some states are shifting from only chemical sampling to an emphasis on biological monitoring for their 305(b) assessments. In their water quality assessment reports to Congress in 1992 and 1994, several states used biological assessments to determine the extent of attainment or nonattainment of the aquatic life use designations for their streams (Fig. 8-2). These data should not be used for comparing one state to another because the data — and hence the figures listed in Figure 8-2 — refer to assessed waters only, not to all waters in a given state.

The biocriteria process is a fundamental tool for assessing aquatic life use impairment.

Judging Use Impairment

A key element of water resource management under the Clean Water Act is the establishment and enforcement of standards to protect the nation's surface waters. If these state-developed standards are not met, legal action may be taken against dischargers to protect or restore the water resource. Criteria are scientifically based benchmarks upon which the standards are based, and biological criteria are benchmarks arrived at from direct measurements of the responses of resident fish and other organisms to conditions in the water. Chemical, physical, and whole effluent criteria are indirect or surrogate measurements of degradation based on the amount of pollutant present in the waters, not the actual condition of the biota.

Biocriteria are designed to reflect the designated use of the water resource selected by the state so failure to meet these criteria is a violation of the standards derived from them. Thus, the biocriteria process is a fundamental tool for directly assessing aquatic life use impairment.

In Ohio, use attainment or nonattainment is determined using biocriteria based on both macroinvertebrates and fish. Full use attainment occurs if all criteria are met. Partial use attainment occurs if one assemblage meets its criteria though the other does not. The status is nonattainment if none of the biocriteria are met, or if one assemblage indicates poor or very poor performance, even though the other indicates attainment.

CASE STUDY — Ohio

STATE	LOCATION	DATES
Ohio	Upper Hocking River	1982–1991

The Hocking River basin covers 1,197 square miles in southeast Ohio, and flows through the cities of Lancaster, Logan, Nelsonville, and Athens; each city maintains wastewater treatment facilities (WWTPs) that discharge into the river (Clayton Environmental Consultant, 1992). Historically, the upper Hocking River near Lancaster has been one of the most severely degraded river segments in the state (Ohio Environ. Prot. Agency, 1982). Throughout the 1970s and early 1980s, the river was severely impacted by industrial effluent, combined sewer overflows (CSOs) and inadequate treatment at the Lancaster WWTP (Ohio Environ. Prot. Agency, 1985). The severe chemical impacts — low dissolved oxygen, and high levels of ammonia, lead, cyanide, cadmium, and phenolics — resulted in gross organic enrichment, heavy metal contamination, significant levels of in-stream toxicity, and periodic fish kills. Invertebrate studies of this portion of the river revealed a severely degraded biological condition with little downstream recovery (Fig. 8-3).

Consequently, the city of Lancaster began upgrading its WWTP in 1986 and reached full operation in 1989. The upgrades, sewer rehabilitation, elimination of bypasses, and the addition of a pretreatment program to remove metals, substantially improved both the water quality and the resident aquatic communities.

The Upper Hocking River has since exhibited the greatest improvement in biological performance of any river system in the state, although its recovery is not yet complete. In 1982, the biological communities downstream of the Lancaster WWTP and CSOs reflected the grossly polluted and acutely toxic conditions. None of the 20.5 miles from Lancaster to Logan attained their WWH standard, and 75 percent of them were in poor or very poor condition. In 1990, only 8.7 miles were still in the nonattainment category, while the rest achieved partial or full attainment and the average ICI score for that portion of the river rose from 6.9 to 42, a sevenfold improvement in the invertebrate community index (ICI).

Macroinvertebrate community performance (as measured by the ICI) improved dramatically, largely in response to the improved water quality. The fish community has substantially improved as well, although serious

Biocriteria establish conditions based on attributes of the resident biota which protect the level of aquatic life designated for the water resource by a state or tribe. Failure to meet the biocriteria is evidence of an impaired water resource.

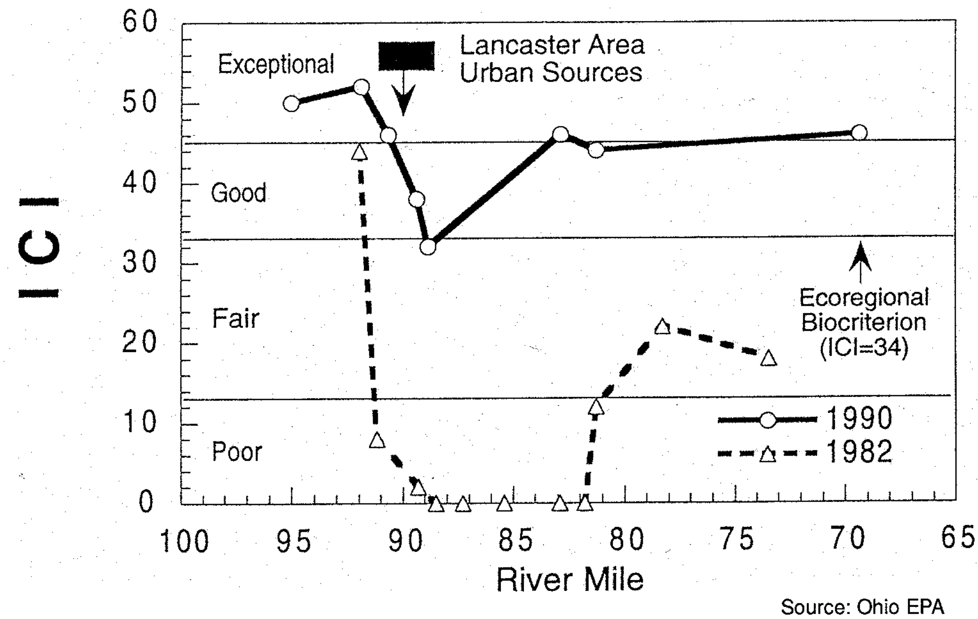


Figure 8-3.—Temporal trends in the improvement of the Upper Hocking River, 1982 - 1990 (adapted from Ohio EPA).

habitat alterations (e.g., channelization, bank erosion, and siltation) continue to inhibit silt-sensitive species. As seen in Figure 8-3, the biocriteria process with its well-defined criterion, careful surveys, and documented biotic indices clearly reveals not only impairment, but management response efforts and the magnitude of the subsequent recovery.

Diagnosing Impairment Causes

An underlying theme of biosurveys and biocriteria is to demonstrate the type and extent of impairment at study sites so proper management can be initiated.

An underlying theme of biosurveys and biocriteria is to demonstrate the type and extent of impairment at the sites being evaluated so that proper management can be initiated. This demonstration can be done by comparing the attributes of aquatic communities at these sites with those found at sites that are unimpaired or minimally impaired. All human-induced alterations affect biological integrity simply by impacting the five environmental factors that affect and determine water resource quality. As discussed in chapter 5, the environmental factors of importance to the stream biota are the site's

- energy base
- chemical constituents
- habitat structure
- flow regime, and
- biotic interactions.

These factors not only influence the aquatic biota; they also affect other elements and processes that normally occur along the stream or river gradient.

Their identification provides an important indicator of the type, locale, and extent of remedial or protective management efforts that should be taken. For example, anthropogenic impairment may result from nutrient runoff of fertilizers; improper use or disposal of chemical toxins; conversion to cropland or other land use modifications; flow alterations; or overfishing. The evaluation of biological and habitat data collected in the biosurvey-biocriteria process can help reveal these causative elements. For example, the biological data will suggest whether overfishing or stocking are factors, or whether disease (which is not strictly anthropogenic) may also be a contributing factor. The habitat data will divulge any structural or sedimentation rate changes, and attendant or subsequent water quality tests will further define toxic or other problems of chemical origin.

An example in West Virginia involved stream degradation resulting from sewage, mining, and urbanization (Leonard and Orth, 1986). Here fish assemblage measurements were indexed in a "cultural pollution index" or CPI (derived from the IBI) to assess watershed and stream quality based on the assumption that assemblage features change consistently with stream degradation. Some fish community attributes respond more quickly than others to stream degradation (Angermeier and Karr, 1986; Karr et al. 1986). However, each metric of the index is sensitive within a different range of stream degradation. In these small coolwater streams of West Virginia, the CPI was sufficiently broad to rank the degree of degradation variously caused by mining, sewage, and urbanization. This study indicates that biotic indexes and criteria can be developed to reflect both the characteristics of regional fish populations and the particular forms of pollution or disruption they encounter.

Human-induced alterations may occur as chemical contamination (point or nonpoint) or as a variety of other effects such as flow alteration or habitat modification.

CASE STUDY — Delaware

STATE	LOCATION	DATES
Delaware	Statewide	1991–1994

In 1994, the Delaware Department of Natural Resources and Environmental Control (DNREC) completed an assessment of the physical habitat conditions of nontidal streams throughout the state. Based on a sampling of 189 sites, only 13 percent were found to be in "good" condition while 87 percent were found to be in either "fair" or "poor" condition. "Good" conditions were defined as comparable to reference conditions. These results have a 95 percent confidence interval of plus or minus 6 to 8 percent. Results were also reported separately for each of the three Delaware counties and for the Piedmont and Coastal Plain ecoregions. The impairment in the Piedmont ecoregion was caused by urbanization and stormwater while the impairment in the Coastal Plain was caused by agriculture and channelization. This assessment is published as Appendix D of the state's 1994 305(b) report.

This information builds on biological data collected at the sites in the Coastal Plain in 1991 and published in the state's 1992 305(b) report. This report concluded that 72 percent of the nontidal streams in Kent and Sussex Counties (Coastal Plain ecoregion) had "good" macroinvertebrate communities compared to 28 percent that were determined to be in "fair" or "poor" condition. Further analysis has shown that degraded physical habitat was the principle cause of the biological impairment; 81 percent of the sites with "poor" biology had "poor" physical habitat (Fig. 8-4). Further water quality studies have implicated the loss of shade and its effects on dissolved oxygen and temperature as key factors that contributed to

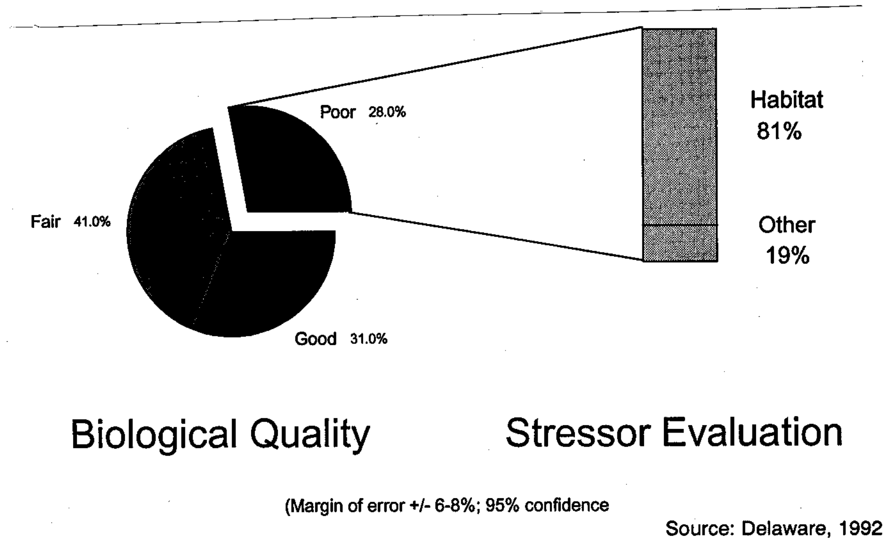


Figure 8-4.—Assessment summary, Kent and Sussex Counties, Delaware, 1991.

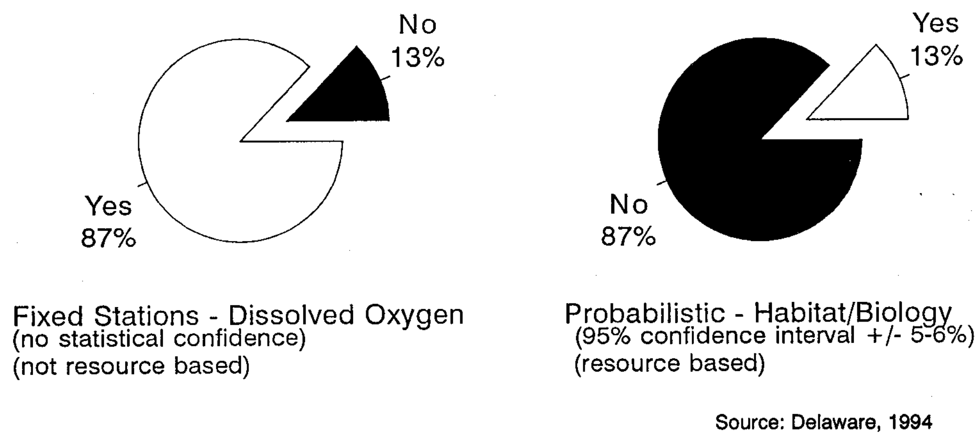


Figure 8-5.—State of Delaware 1994 305(b) report, aquatic life use attainment — all nontidal streams.

the biological impairment. A statewide survey of the biological condition of nontidal streams is currently under development.

Prior to the use of biological and physical habitat measures, Delaware used dissolved oxygen (DO) to judge attainment or nonattainment of aquatic life uses. In the 1994 305(b) report, the state reported that 13 percent of its streams were not attaining aquatic life uses based on DO data. However, 87 percent were found to be impaired based on biological and physical habitat measures (Fig. 8-5). The lower estimate of impairment using DO results from (1) sampling during the day when DO levels are the highest, (2) disproportionate sampling of larger streams with better habitat and more assimilative capacity than smaller streams, and (3) a focus on point sources many of which are meeting permit limitations. The higher estimate of impairment using biological criteria and supporting biological community measurements helped reveal a cause of degradation that might not have been identified by other methods. It reflects the impact of nonpoint source activities, primarily urbanization (stormwater) and agriculture, on the state's nontidal streams.

Problem Identification

Monitoring the status and condition of resident communities over time is important to assess trends in the quality of the biota, whether to guard against further degradation or to measure improvement. In the course of such routine monitoring, new problems or conditions are often discovered. In fact, the Florida Department of Environmental Regulation has a specific (unpublished) program underway to determine the environmental damage (or lack thereof) caused by all significant point source discharges in the state. When the Florida DER began permitting point source discharges, staff relied mainly on compliance with numerical chemical standards. Over time, the need to evaluate the effects of these discharges on receiving waters has increased, both to ensure adequate environmental protection and to set priorities for enforcement or remedial action. Emphasis will be placed on detecting losses of biotic integrity through measures of imbalance in the flora and fauna, effects of toxic materials, dominance of nuisance species, and high populations of microbiological indicators.

A two-tiered approach is being used in the Florida program to detect environmental disturbances in receiving waters. Preliminary investigations (screening phase) involve qualitative sampling and analysis of benthic macroinvertebrate assemblages. A reference or background station is established for comparison with an area downstream of a discharge. Using the results of this relatively low intensity investigation, site impairment is ranked from "no" to "moderate" to "severe." If necessary, subsequent studies on dischargers (definitive phase) will use a more quantitative, multiparameter sampling regime. According to the Florida Department of Environmental Regulation, study parameters (such as macroinvertebrates, periphyton, macrophytes, bacteria, bioassays, sediment analysis, and physical and chemical analyses) are well suited for detection of violations.

The Arkansas Department of Pollution Control and Ecology addresses screening level monitoring using rapid bioassessment at paired stations that bracket pollutant sources for impact identification. As was shown in Figure 5-2, the initial rapid bioassessment screening may result in the application of other biological and chemical methods, after which an on-site decision can be made for subsequent action. In situations where "no impairment" or "minimal impairment" classifications are met, field efforts are discontinued until further information indicates a problem. Streams classified as "substantially" or "excessively" impaired trigger additional investigative steps that employ a variety of methods (Shackleford, 1988).

Monitoring the status and condition of resident communities over time is important to assess trends in the quality of the biota, whether to guard against further degradation or to measure improvement.

CASE STUDY — Maine

STATE	LOCATION	DATES
Maine	Piscataquis River	1984-1990

The Piscataquis River, with a drainage area of about 250 square miles northwest of Bangor, runs near the town of Guilford (Clayton Environmental Consultants, 1992). For many years, untreated manufacturing water from a textile mill and untreated domestic sewage from Guilford significantly impacted the river. In an attempt to improve the quality of the waterbody, the town of Guilford constructed a publicly owned treatment works (POTW), which was completed in June 1988. The POTW has aerated lagoons (detention time of 50 days) and a flow of 0.75 million gallons per day (mgd). Seventy-five percent of the total inflow into the plant comes from textile mill waste; the remaining 25 percent from domestic sewage.

Maine's water quality standards designate a specific level of biological integrity that each class of water must maintain. To meet the standards for a Class A water, the aquatic community must be "as naturally occurs" and specific definitions are used to identify ecological attributes that may be tested to determine if the standards are being achieved.

Maine's Department of Environmental Protection uses a multivariate statistical model to predict the probability of attaining each classification. The model uses 31 quantitative measures of community structure, including the Hilsenhoff Biotic Index, Generic Species Richness, EPT, and EP values.

Monitoring of the Piscataquis River occurred at sites upstream and downstream of the textile mill in 1984, 1989, and 1990, and at a site downstream from the POTW in 1989 and 1990. Before 1988, benthic macroinvertebrate samples collected downstream of the mill revealed a severely degraded community consisting primarily of pollutant tolerant organisms. The macroinvertebrate samples indicated that the waterbody failed to meet the lowest aquatic life standards allowed by the state, although chemical water quality parameters (e.g., biochemical oxygen demand) collected at the site were meeting standards. Chemical parameters alone are insufficient to detect every water quality impairment.

Following the rerouting of the textile mill waste and the completion of the POTW in 1988, the river recovered quickly. Monitoring data, collected during the summer of 1989, revealed a substantially improved macroinvertebrate community (Fig. 8-6). Pollution-sensitive organisms were abundant and EPT values had increased from 1 in 1984 to 17 to 20 in 1989 and 1990. The generic richness improved from 6.35 in 1984 to 38 in 1990. The site now fully supports the aquatic life standards of Class A waters.

Other Applications of the Process

■ **Regulatory Assessments.** The biocriteria process is excellent for assessing the adequacy of NPDES permits to accomplish their intended purpose. As indicated earlier in this text, biological parameters are not recommended as permit limits at this time. But an ideal way to evaluate the success of the permit is to compare downstream biota to upstream or regional reference conditions and biological criteria. If the biota are not sufficiently protected as indicated by a downstream survey, the permit should be reviewed and perhaps revised. This biological review should be scheduled each time a permit is due for renewal.

■ **Management Planning.** This application was implied in several of the examples used in this chapter. Streams in a particular ecoregion can be ranked on the basis of their index scores and relative compliance with biocriteria. The natural resource manager can then assign priorities to individual streams or groups of streams for protection, further investigations, or remedial management depending on the availability of personnel and funding resources. That is, a rational decision with a reasonable ex-

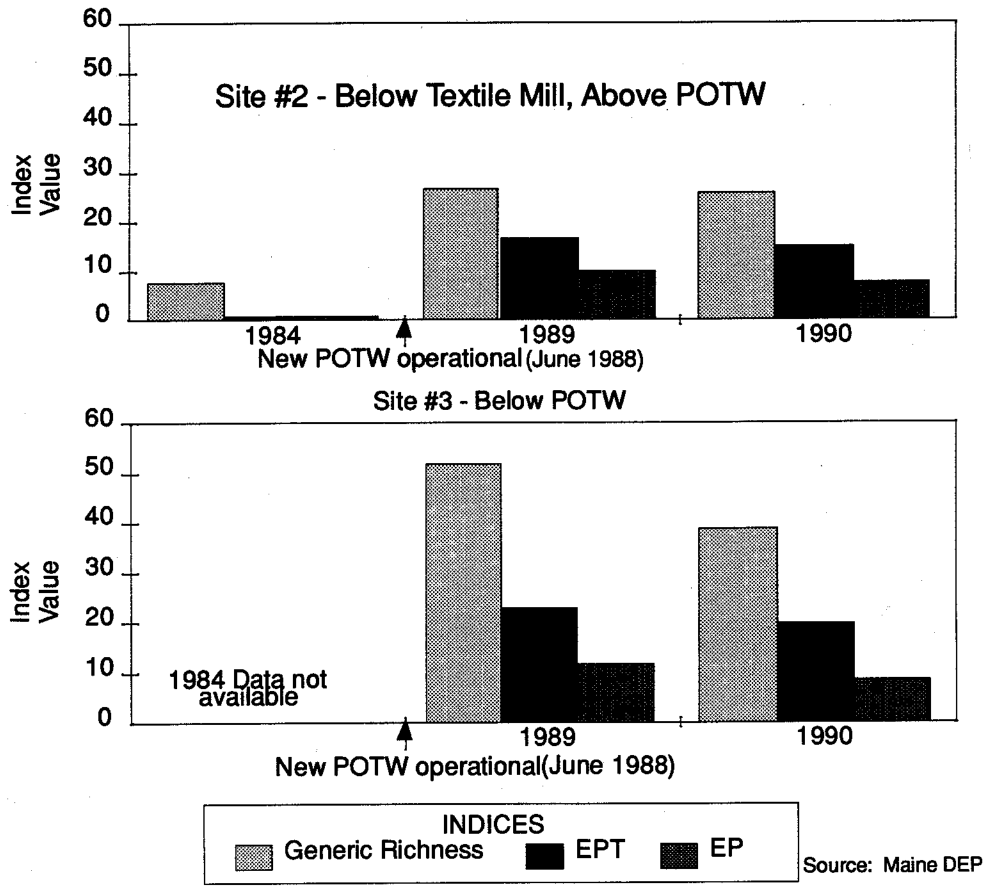


Figure 8-6.—Macroinvertebrates in the Piscataquis River, Maine, 1984-1990. New sewage treatment plant became operational in June 1988 (arrow).

pectation of results can be used to determine which streams will receive attention in any given year.

■ **Water Quality Project and Techniques Evaluation.** When a management plan is implemented, the changed land use practices, bank erosion control structures, and effluent diversion or treatment practices applied can be evaluated for effectiveness by applying the biocriteria process as a "before," "during," and "after" monitoring scheme. If results are as hoped for — as they were, for example, in the Maine case study — the manager can apply the technique to similar problems on other streams. If there is little or no change in the biota, more work is indicated and the technique obviously is not ready for application elsewhere.

■ **Status and Trends Documentation.** This task is one of the primary functions of the biocriteria process and should not be overlooked in discussing other uses of the approach. As an ongoing program, the biosurvey-biocriteria process provides perhaps the best, most direct and comprehensive assessment of water resource condition available to us. Annual surveys of the biota not only refine the biocriteria, but are the basis of state and EPA reports to the nation on the status of surface waters and on our relative success or failure to protect these valuable resources.

Suggested Readings

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